

An Innovative Requirements Solution: Combining Six Sigma KJ Language Data Analysis with Automated Content Analysis

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SEPGSM 2009 North America
Perform at a Higher Level

March 23-26
San Jose California



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Report Documentation Page			<i>Form Approved OMB No. 0704-0188</i>	
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1. REPORT DATE MAR 2009	2. REPORT TYPE	3. DATES COVERED 00-00-2009 to 00-00-2009		
4. TITLE AND SUBTITLE An Innovative Requirements Solution: Combining Six Sigma KJ Language Data Analysis with Automated Content Analysis			5a. CONTRACT NUMBER	
			5b. GRANT NUMBER	
			5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)			5d. PROJECT NUMBER	
			5e. TASK NUMBER	
			5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Carnege Mellon University, Software Engineering Institute, Pittsburgh, PA, 15213			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S)	
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited				
13. SUPPLEMENTARY NOTES				
14. ABSTRACT				
15. SUBJECT TERMS				
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 31
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified	19a. NAME OF RESPONSIBLE PERSON	

Requirements Engineering Challenge: Applying Measurement & Analysis to Qualitative Problems

Users & customers often have **unrealistic performance expectations.***

To meet this challenge in military acquisition, it is not enough that

- program managers begin to collect unbiased data to analyze project costs & projections.
- programs perform technology maturation activities, competitive prototyping or Preliminary Design Reviews (PDRs).

Most importantly,

- Mutual understanding of capabilities in context & what it takes to enable them need to be established **before** a project is initiated among those who
 - determine what capabilities are needed
 - write requirement specifications
 - acquire the systems that meet specifications,

so that appropriate measures of performance & other **quality attributes** of the capabilities & their enabling systems can be determined and aligned.

* OPINION : Reforms for the Department of Defense, by Sen. Carl Levin (D-MI), *Niles Star*, Michigan, 03/11/2009 re the Levin-McCain 2009 Weapons Systems Acquisition Reform Bill



A Promising Solution

A key to understanding ***quality attributes*** is handling qualitative data, which in large part is language data, & making it quantitative.

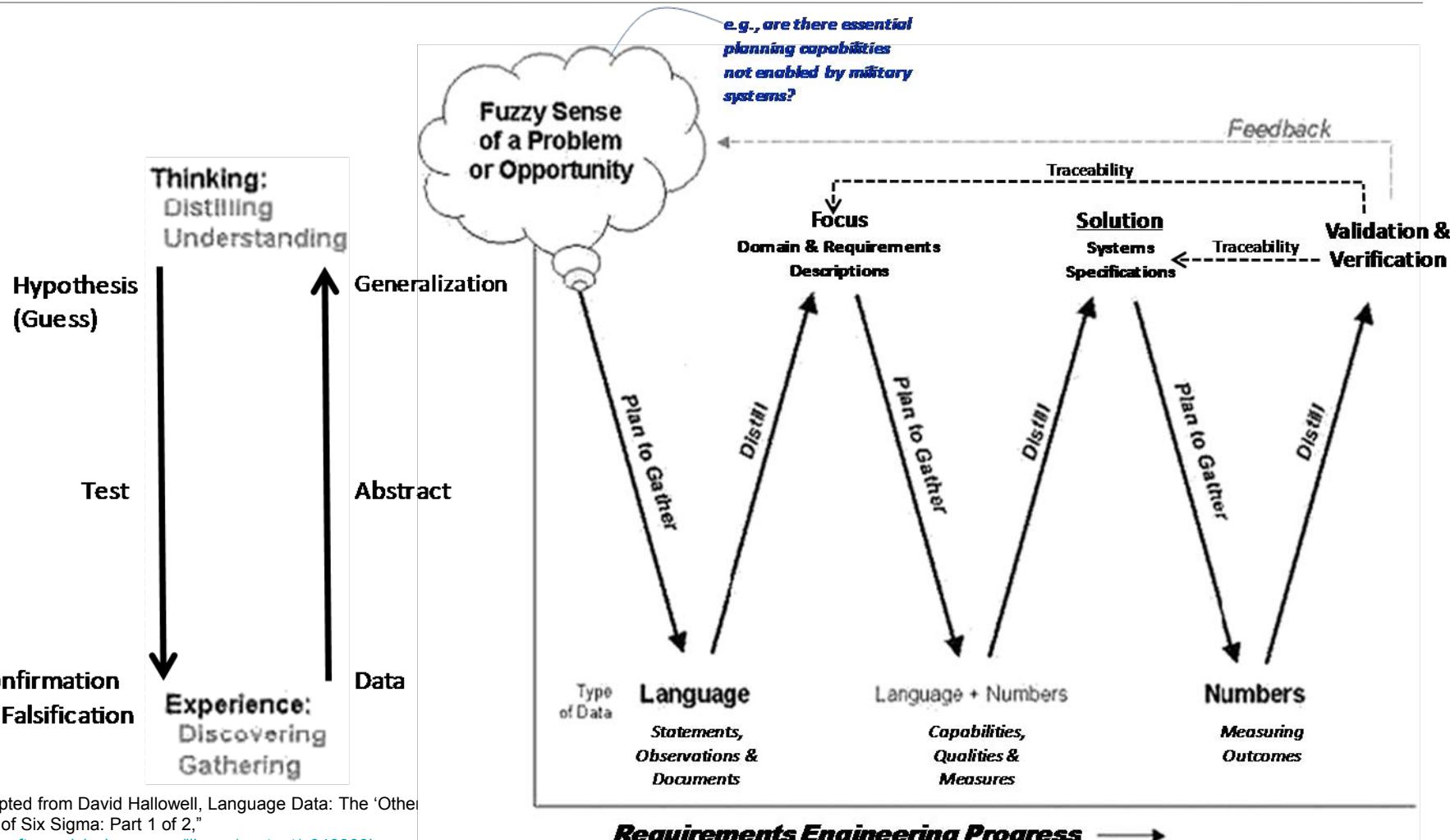
Two complementary language data techniques are being used

- KJ Analysis
 - Structured methods for eliciting & clarifying/interpreting semantic meaning of textual information
 - That automated text analysis simply does not have
- Semi-automated content analysis based on automated text analysis
 - Enables more input from more stakeholders and identifies concepts in common that enables consistent applications of KJ across time & sites

Merging the two allows understanding of language data crucial for requirements & their measured validation.



Language Data: “The Other Data of Measurement & Analysis”* for Requirements Engineering



* Adopted from David Hallowell, Language Data: The ‘Other Data’ of Six Sigma: Part 1 of 2,
<http://software.isixsigma.com/library/content/c040303b.asp>



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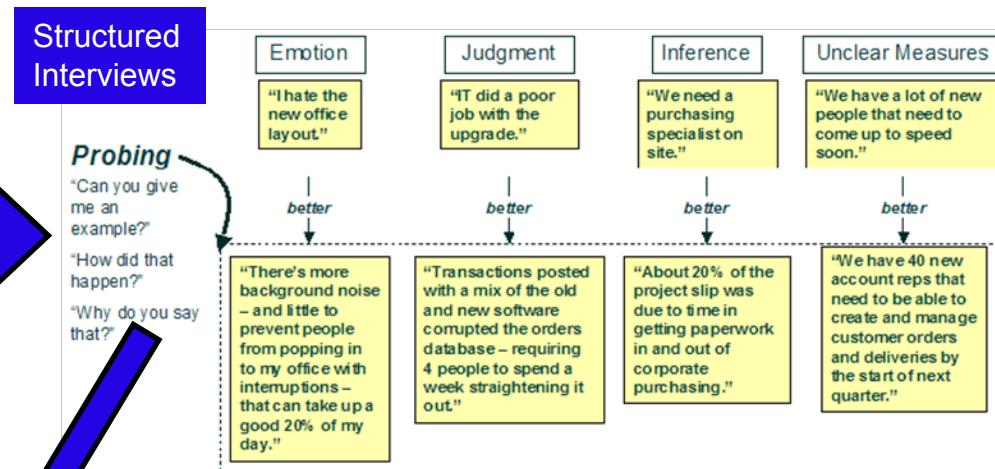
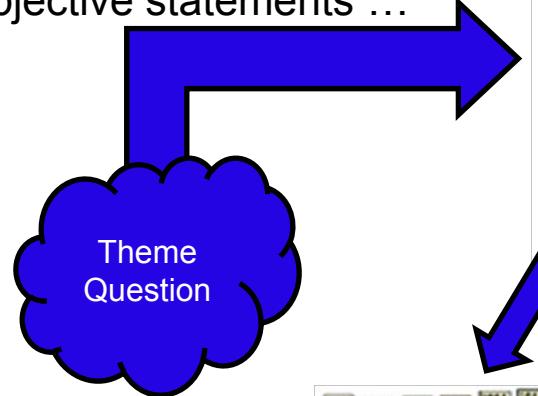
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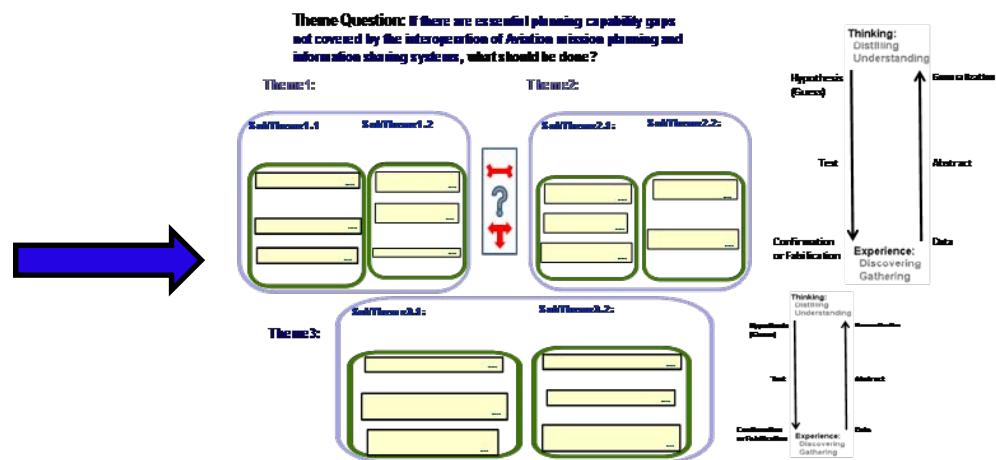
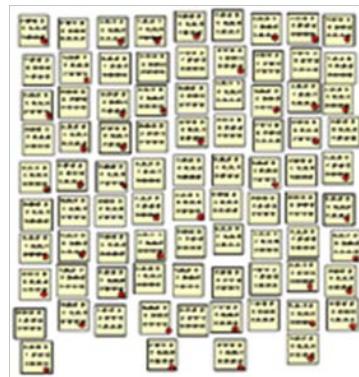
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KJ – a Method for Collaborative Processing of Language Data

KJ (named after Jiro Kawakita) is a method for transmuting *tacit* knowledge into *explicit* and more & more objective statements ...



... and refining a collection of these statements into a 2-D *patterned representation (KJ template)* that conveys lots of information and related thought processes for those communicating asynchronously.



Adopted from David Hallowell, Language Data: The 'Other Data' of Six Sigma: Part s 1 & 2,
<http://www.isixsigma.com/library/content/c040303b.asp>



Distilling Meaning in Language Data: Benefits of Combining KJ with Automated Content Analysis

Content analysis (CA) methods to analyze large bodies of textual documentation have existed for over seventy years, but until recently were predominantly manual.

- They were used during World War II to predict the bombing of London by analyzing Joseph Goebbels' speeches.
- However, humans cannot read & digest all the documents & recognize *all* the patterns that machines are getting increasingly better at doing.
- Yet humans must interpret the meaning, or lack thereof, of what machines can find.

Benefits of Combining CA & KJ

- *Automated text analysis can process a much richer body of information & provide common concepts for KJ participants to establish consistency from group to group.*
- *KJ analysis provides a framework for collaborative interpretation of concept maps produced by CA.*

Upshot: The combination is a hybrid that alters both CA & KJ but that generates insights that neither could produce alone.

Insuring Consistency & Completeness Across KJ Settings is a Problem

To date, KJ analysis has been applied in small, face-to-face one-day workshops where both customer and technologist points of view are represented.

One worry is that results might be quite different if different representatives were assembled on a different day.

An automated language or content analysis approach is being developed to supplement the KJ method so that

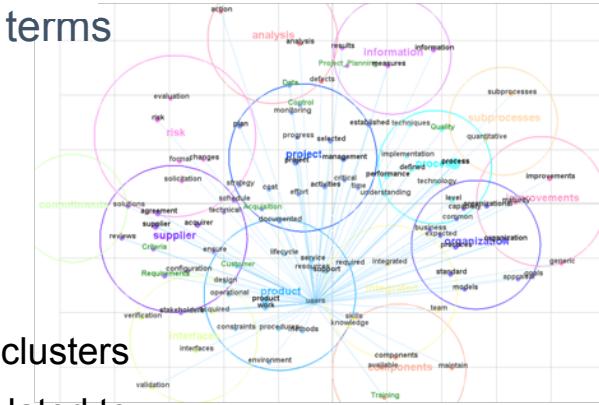
- a significantly larger group of individuals in geographically disparate locations can participate asynchronously.
- additional textual information is captured beyond that in KJ face-to-face sessions:
 - documentation in the form of requirement descriptions & specifications
 - problem and defect report databases
 - open text surveys
- there is more confidence that results are complete and repeatable.



Content Analysis & Concept Maps – a Language Data Computational Processing Method

CA uses automated text analysis tools to identify recurring concepts & clusters of concepts:

- Concepts are synonyms of strongly related **co-occurring terms**
 - constituted in automatically generated affinity lists
 - named by most representative term in affinity list
- Concept Clusters are collections concepts of similar co-occurrence patterns
 - more strongly related to each other than to concepts in other clusters
 - named by automatic selection of the concept most strongly related to other concepts in the cluster

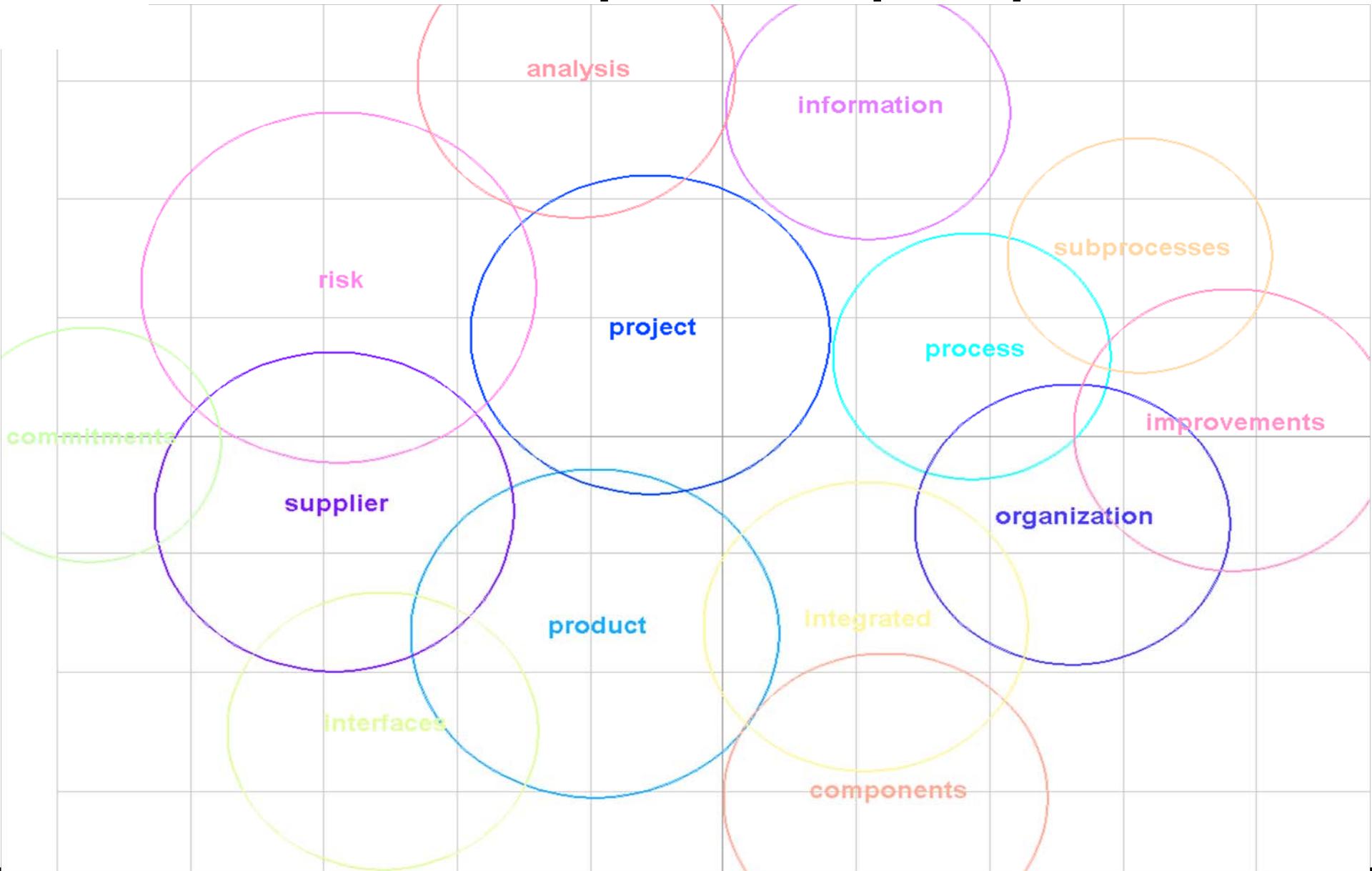


Concept Clusters are represented graphically as Venn diagrams

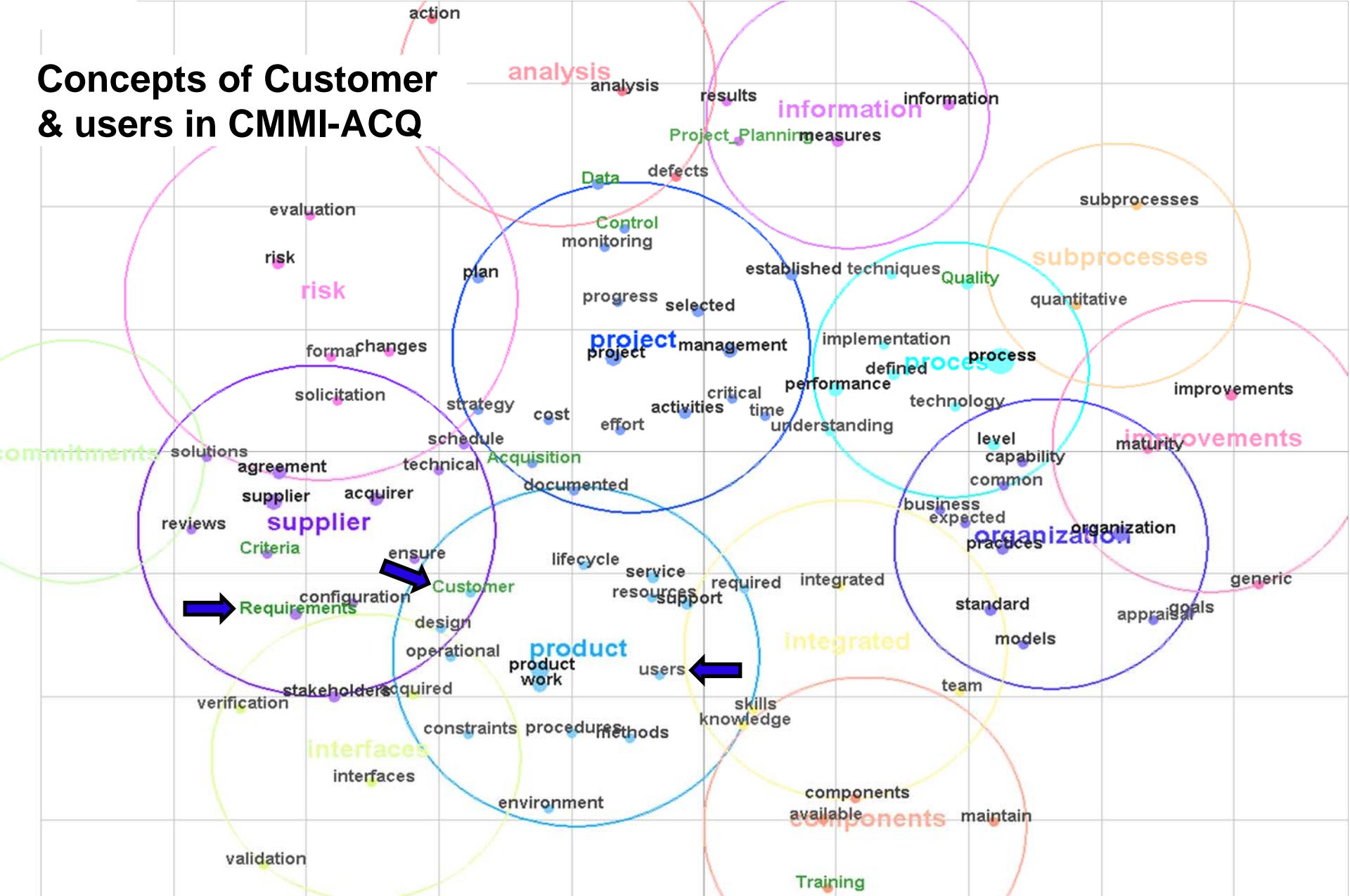
- Concept names labeling dots are in concept clusters represented as circles
- dots can be linked by lines whose brightness represents frequency of co-occurrence
- dots can appear in the overlap of two (or more) circles
- circle size does not always indicate importance since circles can be sparsely populated



A CMMI-ACQ Example: Concept Map Clusters



Concepts of Customer & users in CMMI-ACQ



Handling Language Data Numerically

Ranked Concept List

Concept	Absolute Relative	
	Count	Count
process	2068	100%
project	845	40.8%
organization	815	39.4%
product	812	39.2%
supplier	671	32.4%
performance	536	25.9%
work	510	24.6%
management	504	24.3%
agreement	493	23.8%
information	474	22.9%
plan	450	21.7%
Requirements	417	20.1%
measures	374	18%
acquirer	361	17.4%
risk	345	16.6%
practices	343	16.5%
standard	308	14.8%
improvements	295	14.2%
activities	291	14%
level	290	14%
Quality	259	12.5%
results	257	12.4%
Data	254	12.2%
organizational	253	12.2%
defined	248	11.9%
stakeholders	240	11.6%
selected	235	11.3%
Criteria	234	11.3%
established	224	10.8%
support	220	10.6%
analysis	214	10.3%
changes	209	10.1%
models	194	9.3%
action	194	9.3%
service	193	9.3%
reviews	189	9.1%

The most frequent CMMI-ACQ concepts are listed at the left.

The **absolute count** is the number of text blocks where a concept occurs – highest count set at 100%.

The **relative count** is the percentage of text blocks concepts occur in.

Not surprisingly for a process model, conceptual traces of **process** are found in the most CMMI-ACQ text blocks.

Project and **organization** are the *next most significant thematic concepts*.

These are followed by **product** and then **supplier** all of which are **important to the points made previously**

All are in the top 10% of concepts appearing in concept maps that follow.

Command & Control

Organize

Establish & maintain unity of effort w/ mission partners

Develop Trust

Establish & Cultivate Rel w Msn Partners

Establish & Cultivate Rel w Partner Orgs

Structure organization to mission

Define structure

Assess Staff Capabilities

Delegate Authority

Identify Capabilities Needed

Integrate Capabilities

Establish Commanders' Expectations

Foster organizational collaboration

Establish Collaboration Policies

Establish Collaborative Procedures

Understand

Organize Information

Develop Knowledge and Situational Awareness

Share Knowledge and Situational Awareness

Planning

Analyze problem

Analyze Guidance

Review Rule Set

Review Situation

Determine Need for Action

Prepare Estimates

Apply situational understanding

Assess Available Capabilities

Evaluate Environment

Determine Vulnerabilities

Determine Opportunities

Develop strategy

Determine Force Readiness

Determine Resources

Adapt Strategy

Align Strategy

Develop Assumptions

Develop Objectives

Determine End State

Review Existing Plans

Develop courses of action

Understand Objectives

Develop Options

Establish Selection Criteria

Analyze courses of action

War game courses of actions

Compare courses of actions

Decide

Manage risk

Validate Targets

Formulate Crisis Assessment

Provide Friendly Force Combat Identification

Direct Consequence Management

Select actions

Select course of action

Select Plan

Terminate

Establish rule sets

Establish intent and guidance

Establish Priorities

Establish Standards

Establish Rule Sets

Intuit

Recognize Key Triggers

Modify Actions

Direct

Communicate intent and guidance

Issue Estimates

Issue Priorities

Issue Rule Sets

Provide CONOPS

Task

Synchronize Operations

Synchronize Execution across Phases

Issue Plans

Issue Orders

Establish metrics

Establish Performance Measures

Establish Effectiveness Measures

Monitor

Assess compliance with guidance

Assess Employment of Forces

Assess Manner of Employment

Assess effects

Assess Battle Damage

Assess Effects of Deception Plan

Assess Munitions Effects

Assess Performance

Assess Re-Engagement Requirement

Assess Operational Effects of Strategic Communications

Assess achievement of objectives

Assess guidance

Capability Area

Combining KJ and CA An Example:

Starting with military capability areas & corresponding documentation

and documentation of systems that may enable essential capabilities,

formulate a Theme Question:

Are there essential planning capabilities not enabled by military systems?

Army BC

Functional

Concept (TP)

525-3.3

2007)

Army C2

Doctrine

(FM 6-0

2003)

Planning Aviation

Missions (PAM)

Desired Functions

Description (DFD)

2007

Army Aviation

ISP for Mission

Planning

Operational Capabilities

System Functions



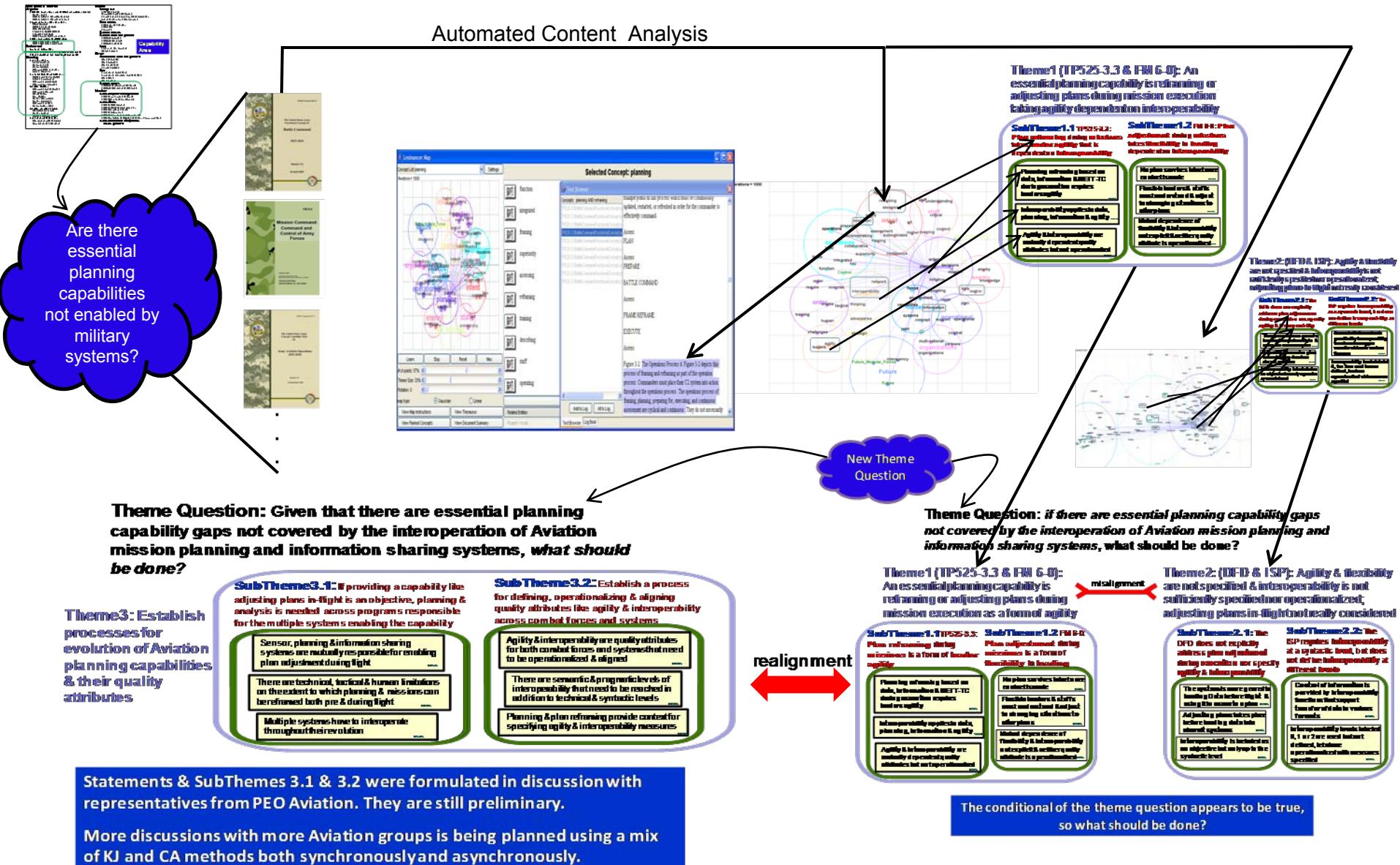
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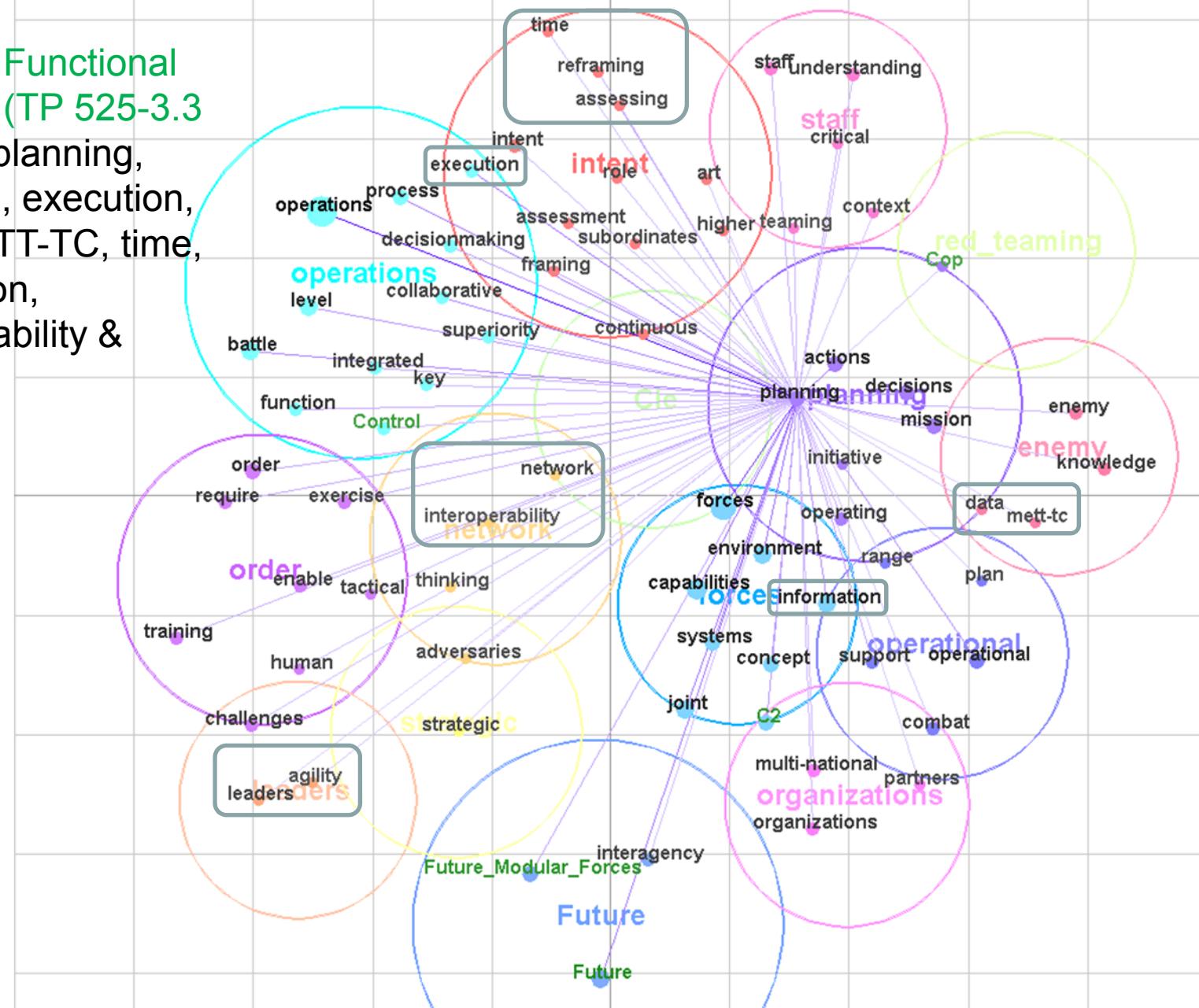
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Combining CA with KJ 2

Automated Content Analysis

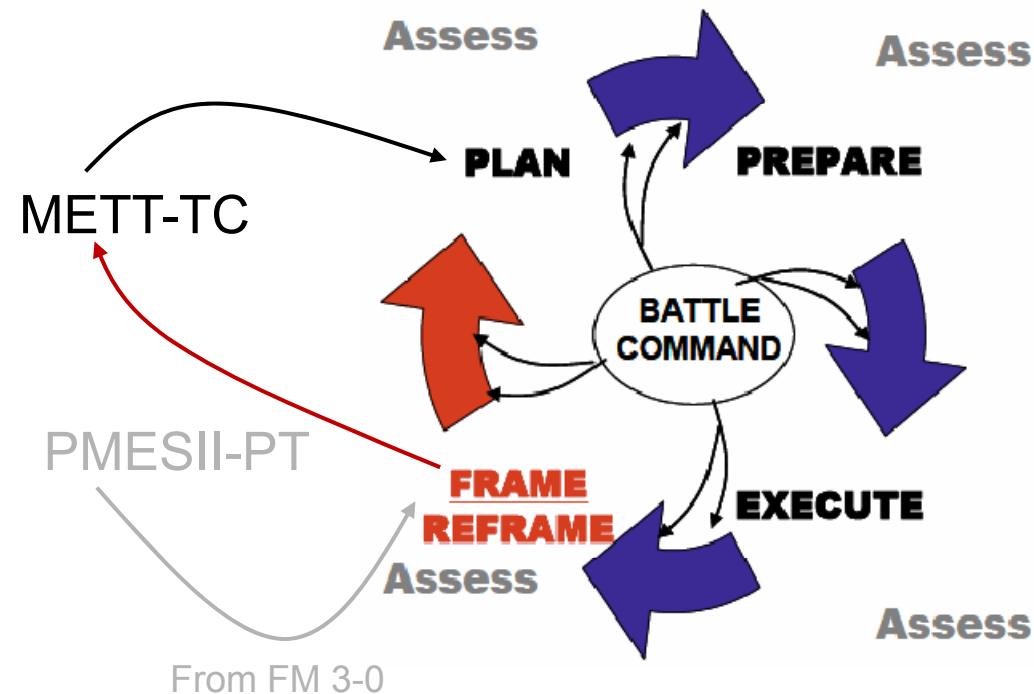


Army BC Functional Concept (TP 525-3.3 2007) – planning, reframing, execution, data, METT-TC, time, information, interoperability & agility



Army Battle Command – Continuous (Re)Planning

(TP 525-3.3 BC Functional Concept)



At the operational and strategic levels, the commander **frames** the existing conditions by interrelating PMESSII-PT factors (Politics, Military, Economic, Social, Information, Infrastructure, Physical & Time).

At the tactical level, commanders consider **METT-TC factors** (Mission, Enemy, Terrain & weather, Troops & support, Time available, Civil considerations) wrt what they are learning from accumulating PMESII-PT information covering both friendly forces & enemy forces.

***"No battle plan survives contact with the enemy."* (Moltke in FM 6-0)**

After initial planning, framing is referred to as reframing.



Elements of a KJ Template

Theme Question: If there are essential planning capability gaps not covered by the interoperation of Aviation mission planning and information sharing systems, what should be done?

Themes abstract meaning from groups of subthemes

SubThemes abstract meaning from groups of statements

Key data in KJ are associated concepts formulated in statements

Statements and subthemes are grouped

Theme1 (TP525-3.3 & FM 6-0): An essential planning capability is **reframing** or **adjusting plans** during **mission execution** requires **agility** dependent on **interoperability**

SubTheme1.1 TP525-3.3: Plan reframing during missions takes leader agility that is dependent on interoperability

Planning reframing based on data, information & METT-TC during execution requires leaders agility

Interoperability applies to data, planning, information & agility

Agility & interoperability are mutually dependent quality attributes but not operationalized

SubTheme1.2 FM 6-0: Plan adjustment during missions takes flexibility in leading dependent on interoperability

No plan survives intact once contact is made

Flexible leaders & staffs must understand & adjust to changing situations to alter plans

Mutual dependence of flexibility & interoperability not explicit & neither quality attribute is operationalized

Concepts used in themes, subthemes & statements derived from content analysis are in bold

Concepts Used in KJ Templates Derived from Concept Maps

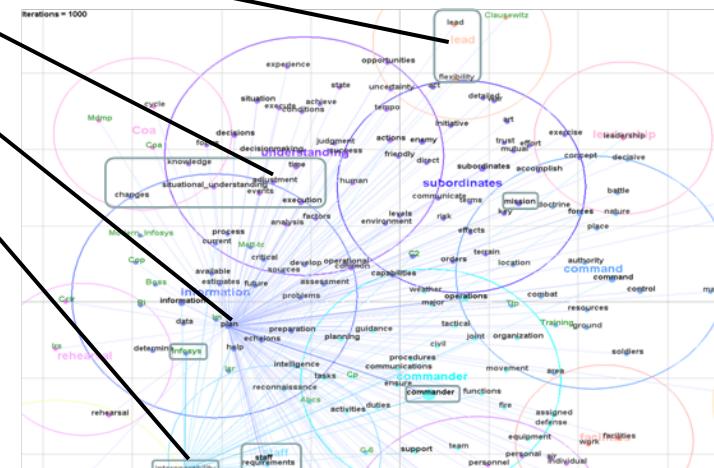
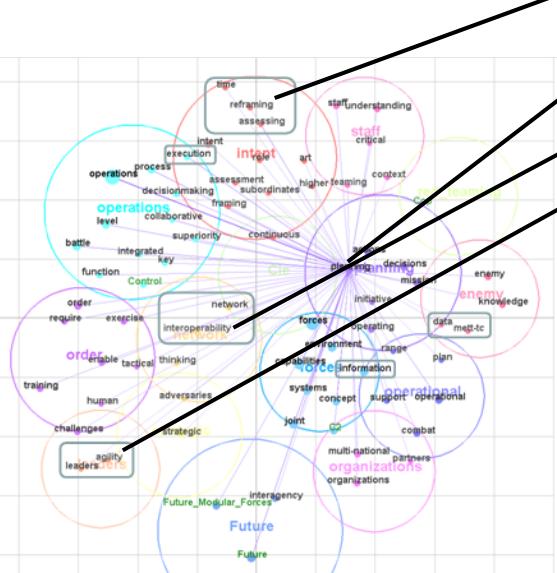
Theme Question: If there are essential planning capability gaps not covered by the interoperation of Aviation mission planning and information sharing systems, what should be done?

Theme 1 (TP525-3.3 & FM 6-0): An essential planning capability is reframing or adjusting plans during mission execution requires agility dependent on interoperability

SubTheme1.1 TP525-3.3: **Play reframing during missions** **to increase agility that is** **dependent on interoperability**

SubTheme1.1 TP 25-3.3: Play reframing during missions to lead agility that is dependent on interoperability

Sub Theme1.2 FM 6-0: Plan adjustment during missions to be flexibility is leading dependence on interoperability



Misalignment between TP 525-3.3/FM 6-0 & PAM DFD/ISP

Theme Question: *Given that there are essential planning capability gaps not covered by the interoperation of Aviation mission planning and information sharing systems, what should be done?*

Theme1 (TP525-3.3 & FM 6-0): An essential planning capability is reframing or adjusting plans during mission execution requires agility dependent on interoperability

SubTheme1.1 TP525-3.3:
Plan reframing during missions takes leader agility that is dependent on interoperability

Planning reframing based on data, information & METT-TC during execution requires leaders agility

Interoperability applies to data, planning, information & agility

Agility & interoperability are mutually dependent quality attributes but not operationalized

SubTheme1.2 FM 6-0: Plan adjustment during missions takes flexibility in leading dependent on interoperability

No plan survives intact once contact is made

Flexible leaders & staffs must understand & adjust to changing situations to alter plans

Mutual dependence of flexibility & interoperability not explicit & neither quality attribute is operationalized

misalignment

Theme2: (DFD & ISP): Agility & flexibility are not specified & interoperability is not sufficiently specified nor operationalized; adjusting plans in-flight not really considered

SubTheme2.1: The DFD does not explicitly address plan adjustment during execution nor specify agility & interoperability

The system is more geared to loading Data before flight & using it to execute a plan

Adjusting plans takes place before loading data into aircraft systems

Interoperability is included as an objective but only up to the syntactic level

SubTheme2.2: The ISP requires interoperability at a syntactic level, but does not define interoperability at different levels

Control of information is provided by interoperability functions that support transfer of data in various formats

Interoperability levels labeled 0, 1 or 2 are used but not defined, let alone operationalized with measures specified

The conditional of the theme question appears to be true, so what should be done?



Given the Misalignment, What Should be Done?

Theme Question: Given that there are essential planning capability gaps not covered by the interoperation of Aviation mission planning and information sharing systems, what should be done?

Theme3: Establish processes for evolution of Aviation planning capabilities & their quality attributes

SubTheme3.1: If providing a capability like adjusting plans in-flight is an objective, planning & analysis is needed across programs responsible for the multiple systems enabling the capability

Sensor, planning & information sharing systems are mutually responsible for enabling plan adjustment during flight

There are technical, tactical & human limitations on the extent to which planning & missions can be reframed both pre & during flight

Multiple systems have to interoperate throughout their evolution

SubTheme3.2: Establish a process for defining, operationalizing & aligning quality attributes like agility & interoperability across combat forces and systems

Agility & interoperability are quality attributes for both combat forces and systems that need to be operationalized & aligned

There are semantic & pragmatic levels of interoperability that need to be reached in addition to technical & syntactic levels

Planning & plan reframing provide context for specifying agility & interoperability measures

A preliminary answer is provided in Statements & SubThemes 3.1 & 3.2 formulated in discussion with a few representatives from PEO Aviation.

Elaboration, confirmation & buy-in has to be achieved with many more stakeholders.

More discussions with more Aviation groups is being planned using a mix of KJ and CA methods both synchronously and asynchronously.



Relationships of all Three Themes

Theme Question: Given that there are essential planning capability gaps not covered by the interoperation of Aviation mission planning and information sharing systems, what should be done?

Theme1 (TP525-3.3 & FM 6-0): An essential planning capability is reframing or adjusting plans during mission execution taking agility dependent on interoperability

SubTheme1.1 TP525-3.3: Plan reframing during missions takes leader agility that is dependent on interoperability

Planning reframing based on data, information & METT-TC during execution requires leaders agility

Interoperability applies to data, planning, information & agility

Agility & interoperability are mutually dependent quality attributes but not operationalized

SubTheme1.2 FM 6-0: Plan adjustment during missions takes flexibility in leading dependent on interoperability

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SubTheme2.2: The ISP requires interoperability at a syntactic level, but does not define interoperability at different levels

Control of information is provided by interoperability functions that support transfer of data in various formats

Interoperability levels labeled 0, 1 or 2 are used but not defined, let alone operationalized with measures specified

realignment

Theme3: Establish processes for evolution of Aviation planning capabilities & their quality attributes

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Sensor, planning & information sharing systems are mutually responsible for enabling plan adjustment during flight

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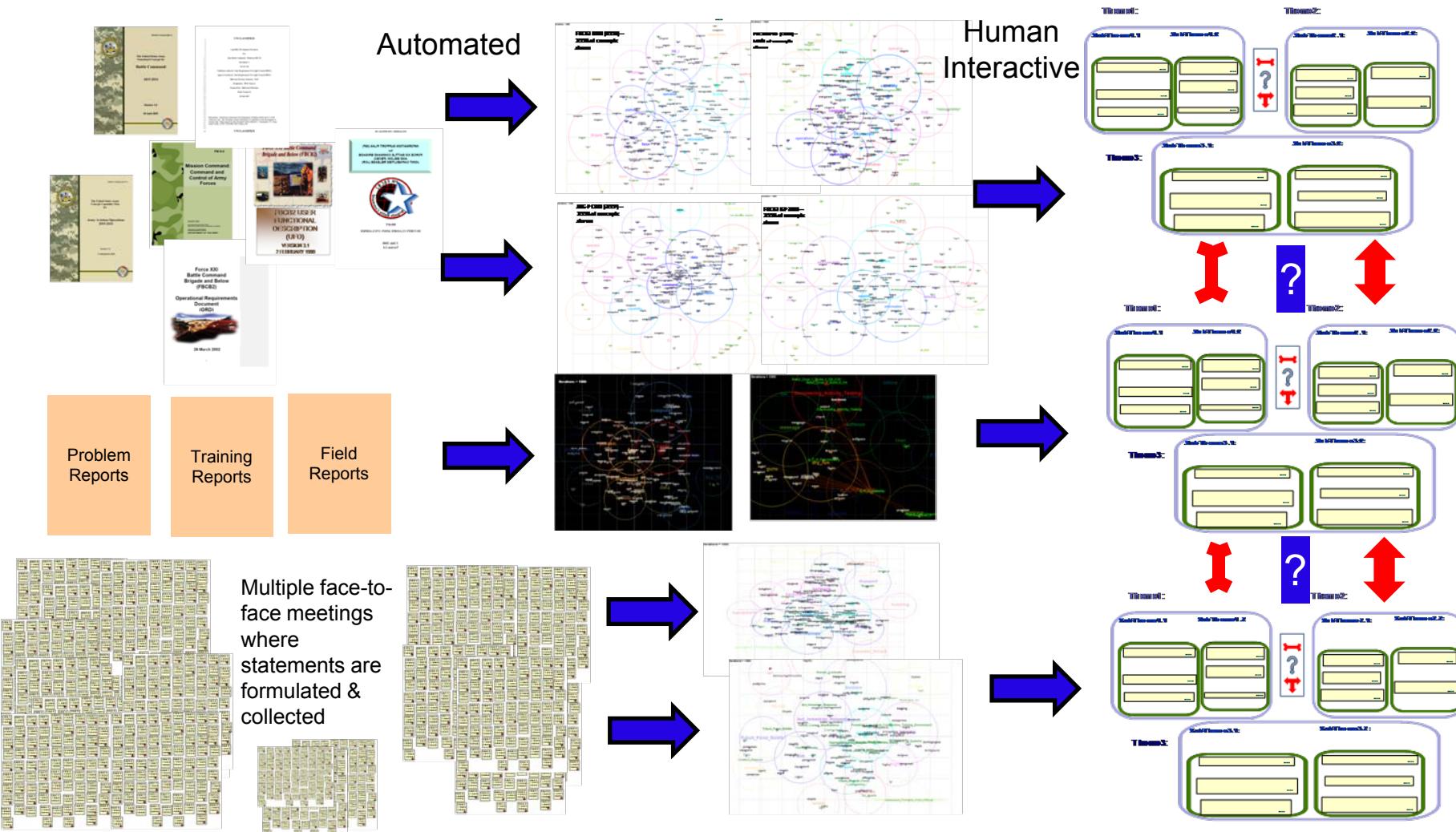
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Planning & plan reframing provide context for specifying agility & interoperability measures



Scaling Up the Process



Concluding Thoughts

What has been shown is the potential for CA to

- uncover misalignments among documents describing capabilities & systems
- identify quality attributes in these documents that need to be better defined & operationalized

These results can be used in KJ analyses in the form of common concepts that can be combined in statements, subthemes & themes in

- multiple face-to-face interview probing
- collaborative interpretation of concept maps derived from different documents leading to determinations of their alignment or misalignment.

So far this combined use of CA & KJ has shown promise when used informally with a few representatives of military organizations.

The next step is to refine the emerging process with greater numbers of people and documents in multiple settings.



Thank you for your attention!

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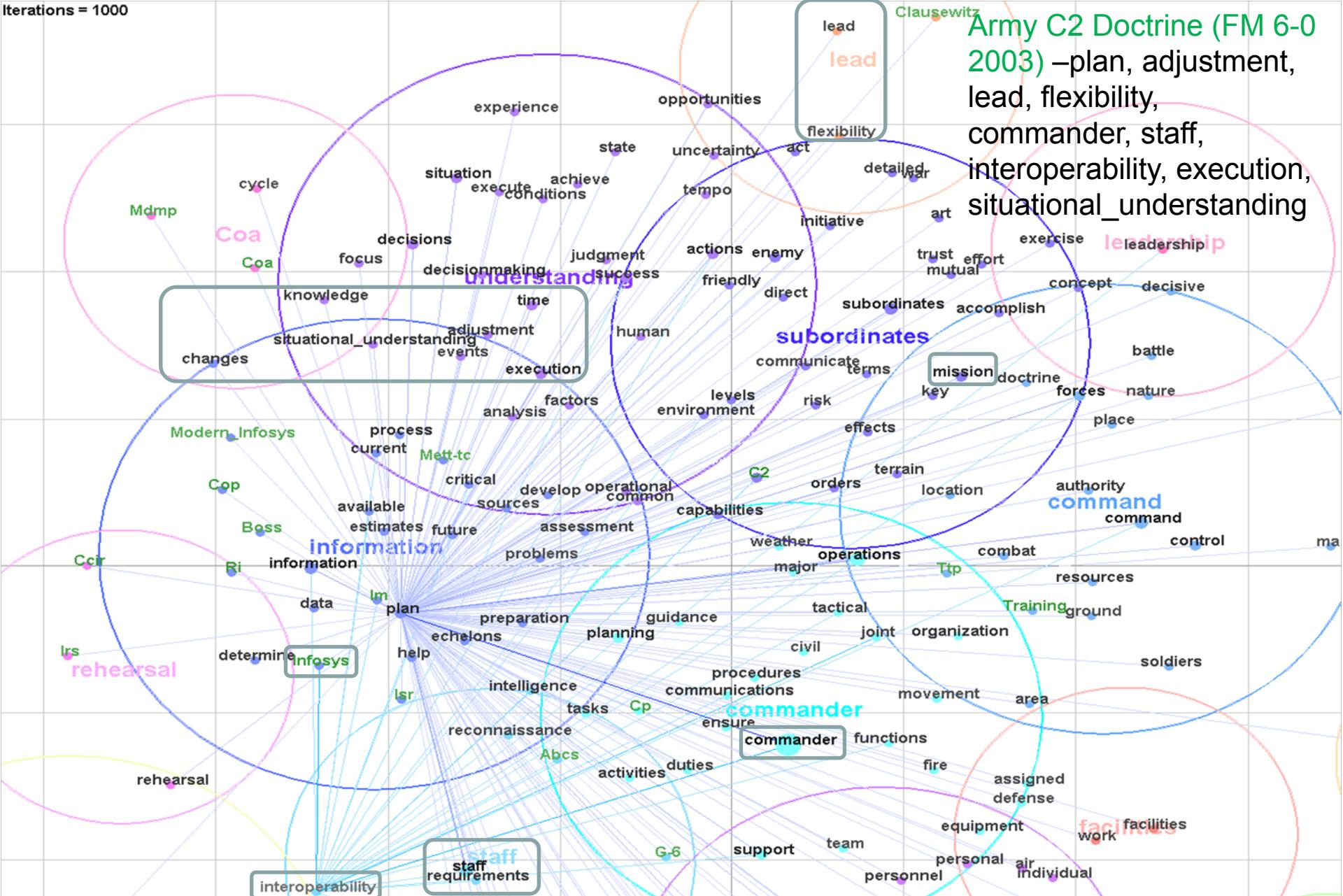


Backup



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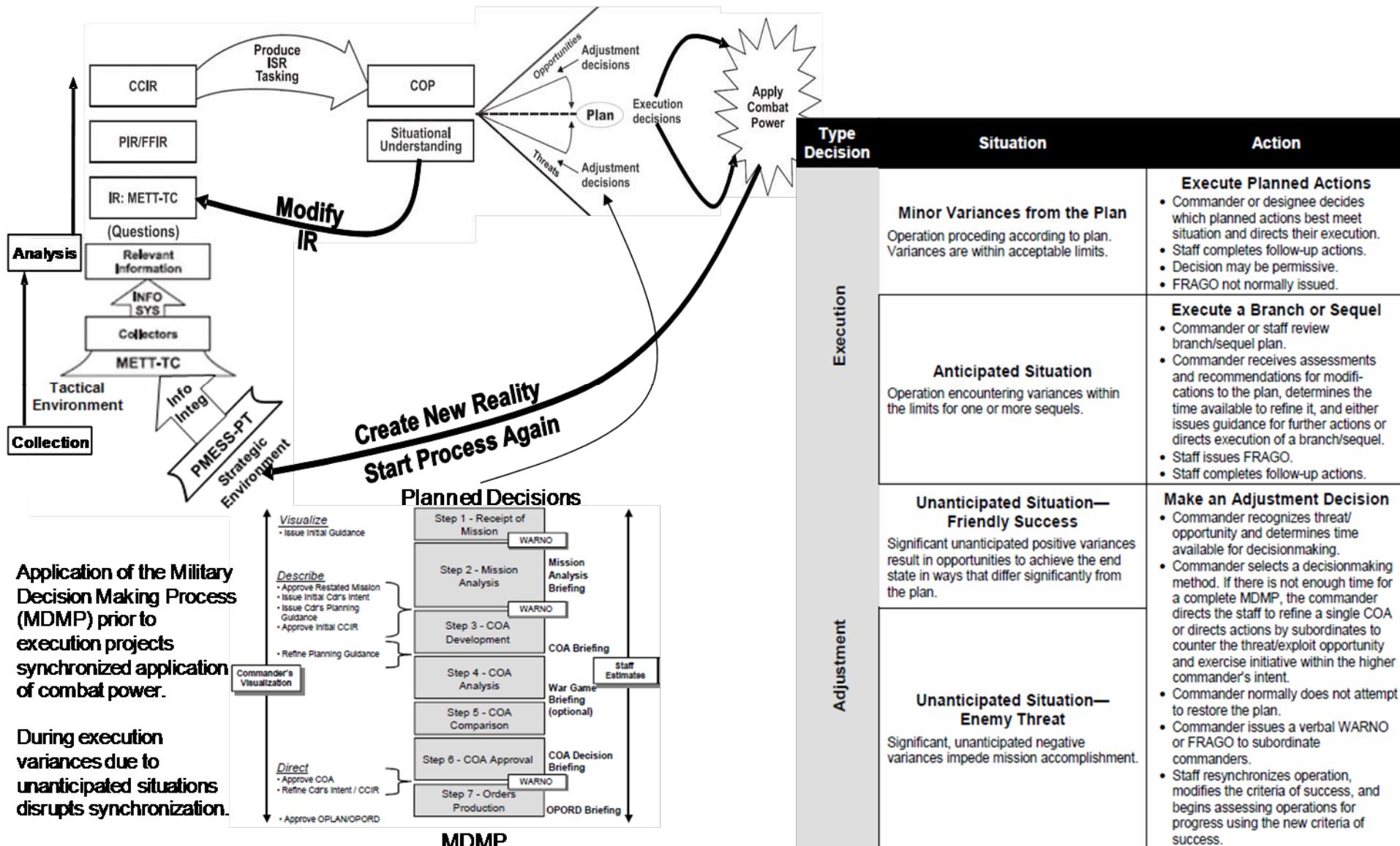


Army C2 Doctrine (FM 6-0 2003) –plan, adjustment, lead, flexibility, commander, staff, interoperability, execution, situational_understanding

ation authority
command

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Army Command & Control Doctrine (FM 6-0)



Interpreting Analysis of TP 525-3.3 & FM 6-0: Quality attributes need to be specified & operationalized

Plan reframing during **mission** execution is a form of **leader agility** (inference from Battle Command graphic TP 525-3.3 and **leaders** cluster in concept map)

- *Agility, as it applies to joint C2, has six key elements: robustness, resilience, adaptability, responsiveness, flexibility, and innovation (TP 525-3.3)*

Plan adjustment during mission execution is a form of **leader flexibility** (inference from and lead cluster)

- *No plan survives intact once contact is made. Tactical flexibility requires flexible leaders capable of adapting to rapidly changing circumstances; and staffs able to recognize significant changes in the situation, and resynchronize the operation by coordinating the changes to alter the plan (FM 6-0).*

Agility & flexibility depend on (semantic & pragmatic) **interoperability**

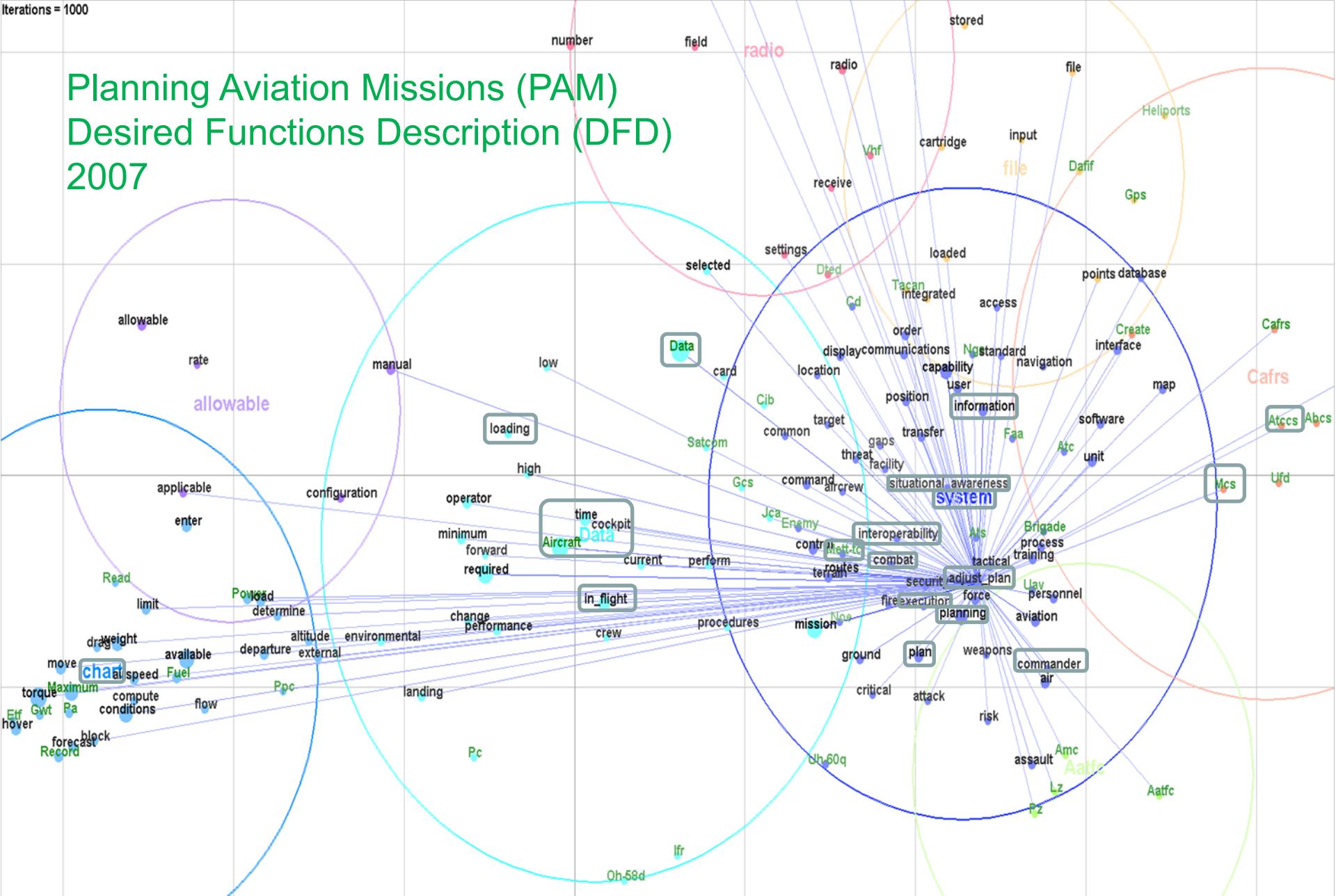
- *in order to share needed information when it is needed & in a form it can be understood and acted on with confidence (TP 525-3.3).*

Agility, flexibility & interoperability are battle command quality attributes

- need to be operationalized with numeric thresholds and objectives specified
- Planning & plan reframing provide context for specifying these measures.



Planning Aviation Missions (PAM) Desired Functions Description (DFD) 2007



Interpreting the Significance of Adjust_Plan in the PAM DFD

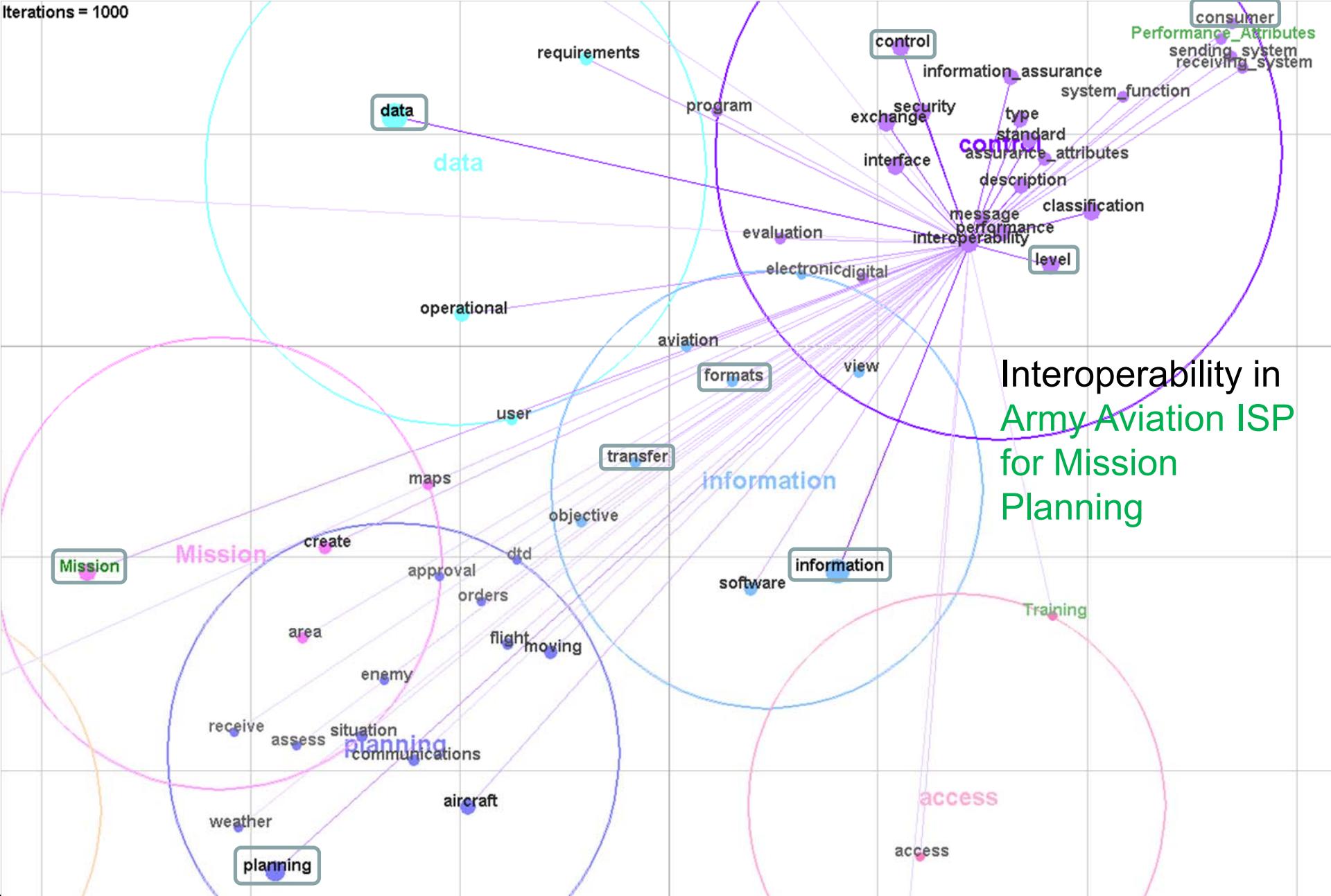
Statements in the document do not explicitly commit to **plan adjustments** in-flight.

While the document says

- *“The ... interface to the Maneuver Control System (MCS) ... provides the aviation commander with continuous updates of the friendly and enemy situation and allows the commander to rapidly **adjust his plan** to accomplish his assigned mission.”*
- it also says, *“The assigned missions, orders and map data are then transferred down to the air crew level where specific air crew mission planning takes place. This mission information is then loaded into the aircraft systems via hardware or digital radio transfer for use during mission execution.”*
- In fact, in conversation with aviation mission planning acquisition people, they asserted their system only served pre-flight planning.

High level **interoperability** requirements are stated, but not clearly defined or operationalized with measures specified.





Interpreting the Significance of Interoperability in the PAM ISP

According to the ISP, most of the **interoperability** functions support **data transfer** in various **formats** enabling the **planning** system to be

- the collector & consolidator of all pertinent battlefield **information** needed for effective aviation **missions** thereby serving as an information **consumer**
- capable of in-flight re-targeting and re-planning (though this is only stated once as an objective)

However, supporting data transfer in various formats is syntactic **interoperability** – not semantic or pragmatic **interoperability** needed for in-flight re-targeting & re-planning.

Interoperability levels labeled 0, 1 or 2 are used but not defined, let alone operationalized with measures specified.

